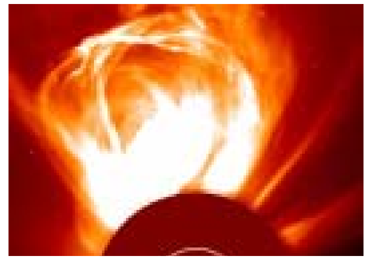
Data Analysis and Generalizations

Solar Wind

STUDENT TEXT


NASA

A coronal mass ejection

The solar wind generated by our Sun is quite different from our Earth's surface winds. Solar wind carries about one million tons of hot plasma, at a temperature of about 10^5 kelvins, away from the Sun every second. Solar wind plasma is a mixture of 95% protons (H^+) and 4% alpha particles (He^{2+}). The remaining 1% is made up of ions of other elements, including carbon, nitrogen, oxygen, neon, magnesium, silicon, and iron, and enough electrons to electrically balance all the positive ions.

This plasma behaves like an electrically conducting fluid, carrying with it a magnetic field arising from systems of electrical currents in the Sun's corona. The strength of this magnetic field decreases inversely with its distance from the Sun. Because plasma particles have sufficient kinetic energy to escape the Sun, the solar wind becomes an extension of the Sun's corona into interplanetary space. The solar wind extends to distances past the farthest spacecraft, currently Voyager 1 at about 75 times the distance between the Earth and the Sun (75 AU or astronomical units).

These solar wind streams are carried at different speeds, varying from 300 to 1000 km/s, independent of the wind's distance from the Sun. Because they are carried at different speeds, the streams collide and rebound, producing low magnetic regions and regions in which the magnetic field is amplified. In the next activity, you will observe solar wind data that shows three types of solar wind called **solar wind regimes—**slow solar wind, fast solar wind, and coronal mass ejections. Slow solar wind is often associated with streamers, visible during a solar eclipse. Fast solar wind emerges from coronal holes in the Sun's atmosphere. Coronal mass ejections are explosive releases of material from the corona. The Genesis spacecraft serves as a catcher, collecting all three types of solar wind samples that will give us clues about the formation of our solar system. However, scientists are especially interested in the data from the fast solar wind. According to Los Alamos National Laboratory space scientist John Steinberg, "The most important sample to us is most likely the sample of the fast wind, because from our measurements in the past of the solar wind, the fast flows are most uniform in elemental composition, in the charge state composition of the ions, and in the density itself. There is probably less variability and a more uniform process that pulls out solar wind in the fast flows. That, we believe, will be our best sample from Genesis."

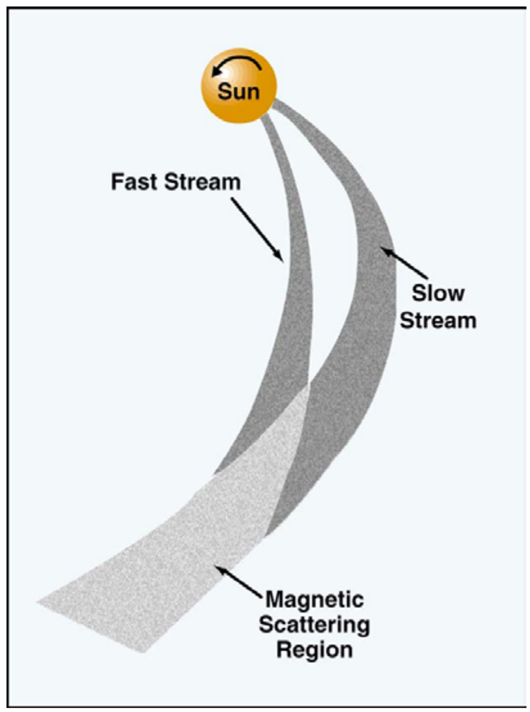


Figure 1a: Solar Wind Regimes

After escaping from the Sun's gravitational field, the solar wind flows outward radially like water from a rotating garden sprinkler. Each drop moves straight out from the source, but the pattern rotates. The streams travel at speeds that vary from 300 to 1000 km/s and are independent of their distance from the Sun. The density of the solar wind varies between 1 and 10 particles/cm^3 and diminishes with the inverse square of the distance from the Sun. Solar activity can cause sporadic order-of-magnitude fluctuations, however.

At 1 AU (Earth's distance from Sun) the spiral makes an angle of about 45° with a radial line from the Sun, as shown in Figure 1a. At this distance, the solar wind is traveling at well over one million miles per hour. Its plasma density is about five particles/cm^3, and its magnetic field strength is typically about 10^{-4} that of Earth's.

Another observation you will make when looking at the solar wind data is **interplanetary shocks**. Interplanetary shocks are easily identified as simultaneous, abrupt jumps in the speed, density, and temperature of protons, alpha particles, and electrons. The term “planet” in interplanetary shocks can be misleading. Interplanetary in this regard really means “in the middle of nowhere.” In other words, these shocks are not associated with planets at all, so the term interplanetary distinguishes these shocks from bow shocks that are associated with planets, asteroids, and any other objects. Interplanetary shocks result from fast wind plowing into slower wind. An interplanetary shock occurs rapidly, within a period of minutes.

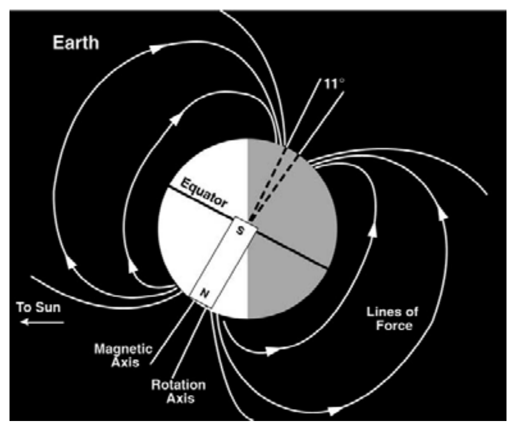
The solar wind actually has a negligible effect on the movements of planets, but it can have other profound effects in its immediate vicinity. Mars and Venus may have lost former oceans, and Mars may have lost much of its atmosphere to space as a direct result of solar wind. But Earth’s magnetic field has protected our atmosphere, our water supply, and its inhabitants from the searing effect of the solar wind’s ionized gases.

Explorer 1

In 1958, Explorer 1 first discovered the Earth's magnetic field when it detected a region of intense radioactivity as it orbited elliptically around the Earth. Later in the same year, radiation detectors aboard Explorer 3 observed large populations of very energetic, charged particles trapped in two large belts that completely encircle the Earth. In the inner belt, which extends from an altitude of 2,000 kilometers to 5,000 kilometers above the Earth, "the energetic particles are mostly protons. The outer belt, where the energetic particles are mostly electrons, starts at an altitude of 15,000 kilometers and is about 6,000 kilometers thick. The behavior of these electrically charged particles is determined by the planet’s magnetic field.

The Earth's magnetic field has two poles, North and South, and the fields’ pull extends far beyond the surface of the Earth. Within this magnetic field, an average of 50 tons of plasma per day flows against the gravitational pull of the Earth, much as the solar wind flows away from the Sun. This plasma contains hydrogen, helium, oxygen, and nitrogen atoms and ions as well as heavy ions.

This optically transparent space around the Earth is its magnetosphere. It is the interaction of the Earth's magnetic field with particles in this region that provides our protection from solar wind plasma. It is also the interaction of Earth’s magnetic field with the solar wind that makes it necessary to position the Genesis collector outside the Earth’s magnetosphere to obtain a “clean” sample of the solar wind.



Earth’s Magnetic Field